

Special Specification 4140

Micropiling



1. DESCRIPTION

Furnish and place micropiling consisting of small diameter steel bar installed in a drilled borehole and steel casing, grouted in place, and conforming to the locations, depth, and details shown on the plans and as described in this special specification.

2. MATERIALS

Provide materials conforming to the following requirements.

- Item 440, "Reinforcement for Concrete;"
- Item 441, "Steel Structures;"
- Item 442, "Metal for Structures;"
- Grade 75 All-Thread reinforcement ASTM A615.
- Grade API N-80 Steel Casing.
- Type B stud connectors as defined in AWS D1.5, Section 7.

- 2.1 **Hydraulic Cement Concrete.** Use materials that meet the requirements of Item 421, "Hydraulic Cement Concrete." Provide a neat cement or sand-cement mixture for the grout for micropiles with a 7-day compressive strength of 3,000 psi and refer to plan for a 28-day compressive strength. Determine grout strength by testing the grout used for the test micropiles in cubes in accordance with Tex-307-D or cylinders in accordance with Tex-418-A. Test further as directed or if the grout mixture is modified. Fly ash may be included in the grout.

Do not use grout mixed in a mobile continuous volumetric mixer.

Provide a grout mix with a minimum water-cement ratio of 0.4 and a minimum specific gravity of 1.85. Test for specific gravity in accordance with Tex-130-E.

When a sand-cement mixture is used for grouting micropiles, provide a grout mixture with a minimum slump flow of 20 in. Test the slump flow of the grout in accordance with ASTM C1611.

The need for stiffer grout may arise when the hollow-stem auger drilling method is used or it is desired to control leakage of grout into highly permeable granular soils or highly fractured rock. In these instances, the Engineer may waive the requirements of slump flow testing.

- 2.2 **Admixtures for Grout.** Provide grout in accordance with Item 421, "Hydraulic Cement Concrete," and in accordance with the plans. Admixtures which control bleeding, improve flowability, reduce water content and retardment set may be used in the grout subject to the approval of the engineer. Comply with manufacturer's recommendations for use of admixtures. Expansive admixtures must only be added to the grout used for filling sealed encapsulations and anchorage covers. Accelerators are not permitted. Admixtures containing chlorides are not permitted.
- 2.3 **Centralizers and Spacers.** Provide centralizers and spacers fabricated from schedule 40 PVC pipe or tube, steel, or material non-detrimental to the reinforcing steel. Wood must not be used.
- 2.4 **Bar Couplers.** Provide bar couplers that develop the full nominal tensile capacity of the All-Thread reinforcing as certified by the manufacturer.
- 2.5 **Steel Casing.** Steel casing splices must develop the required compressive, tensile, and bending strength in accordance with the specified design load in the design and testing of micropile.

3. CONSTRUCTION

- 3.1 **Working Drawings.** Submit complete project specific working drawings for the micropile system to the Engineer, in conformance with Item 5.2, "Plans and Working Drawings" of the Standard Specifications.

Include all information required for the construction and quality control of the piling, including the following:

- Information on headroom and space requirements that verify the proposed equipment for installation can perform at the site;
- Step-by-step procedure describing all aspects of pile installation including personnel, testing, and equipment to assure quality control. Indicate the step-by-step procedures on the working drawings in enough detail so that the Engineer can monitor the construction and quality of the micropiles;
- Details for drilling a plumb hole;
- Details of centralizers;
- Grout mix designs;
- Details and procedures involved in testing components, including grout;
- Pipe and reinforcement splice type and locations;
- Details of equipment and operation for grouting. Include provisions for monitoring grout quality, volume installed, and pressure during installation;
- Information on the minimum cure time and strength requirements of the pile system for test piles;
- Drawing showing micropile location, number, design load, type, and size;
- Submit the following post-construction, within 30 calendar days after completion of work: as-built drawing showing locations of micropiles and lengths; detailed drilling records; grouting records indicating the cement type and quantity injected; micropile test results and graphs.

Allow the Engineer enough time to review the working drawing submittal after a complete set has been received. Do not install micropiling until the Engineer has approved, in writing, the drawing submittal.

- 3.2 **Construction Site Survey.** Contractor is responsible for the field locating and verifying the location of all utilities and existing structure as shown on the plans before starting the work. Maintain uninterrupted service for those utilities and the existing structure designated to remain in service throughout the work. Notify the Engineer of any utility and existing structure locations different from shown on the plans that may require micropile relocations or structure design modification. Additional cost to the Contractor due to micropile relocations or structure design modification resulting from utility locations different from shown on the plans, will be paid as extra work.

3.3 **Installation.** Dispose of material excavated from micropile and not incorporated into the finished project in accordance with the plans and federal, state, and local laws.

Use core drilling, rotary drilling, percussion drilling, auger drilling, driven casing or other acceptable means unless otherwise directed. The micropile can be installed in the drill hole after drilling or it can be advanced by the drill. Extend micropile borehole as needed to achieve the minimum depth and bond length, as depicted on the Plans.

Bond length must exclude soil layers or voids in determining whether the minimum bond length has been achieved. Do not use drilling mud or chemical stabilizers.

Remove foreign material dislodged or drawn into the hole during construction of the micropiles. Remove loose material existing at the bottom of the hole after drilling operations are complete before placing grout.

Bar reinforcement can be installed in the drill hole after drilling or it can be advanced by the drill. Use centralizers when installing steel casing and bar reinforcement. The reinforcing steel must be inserted into the drill hole to the desired depth without difficulty. Partially inserted reinforcing bars must not be driven or forced into the hole. Contractor must redrill and reinsert reinforcing steel when necessary to facilitate insertion. Provide a positive means of support for maintaining the position of the casing and reinforcement until the grout has set.

Micropiles must be primary grouted the same day the load transfer bond length is drilled.

Mix the grout to produce a uniform mixture free of lumps and undispersed cement. Equip the pump with a pressure gauge to monitor grout pressures. Provide a pressure gauge capable of measuring pressure of at least 150 psi or twice the actual grout pressures used by the contractor, whichever is greater. Use grouting equipment capable of pumping the grout in 1 continuous operation. Grout must be placed within one hour of mixing. Continuously agitate the mixed grout during pumping operations.

The grout must be injected from the lowest point of the drill hole and injection must continue until uncontaminated grout flows from the top of the pile. The grout may be pumped through grout tubes, casing, hollow-stem-augers, or drill rods. Temporary casing, if used, must be extracted in stages ensuring that, after each length of casing is removed the grout level is brought back up to the ground level before the next length is removed. Record the quantity of the grout and the grout pressures. Control the grout pressures and grout takes to prevent excessive heave. Fill the entire micropile with grout. The grout tube may remain in the hole provided it is filled with grout.

Grout within the micropile verification and proof test piles must attain design compressive strength as shown on the plan.

3.4 Construction Tolerances

1. Centerline of piling must not be more than 1 in. from indicated plan locations.
2. Pile must be plumb within 1 in. per 10 ft. of depth.
3. Top elevation of pile must be plus 1 in. or minus 2 in. maximum from vertical elevation indicated.
4. Centerline of reinforcing steel must not be more than 0.5 in. from indicated location.

3.5 Micropiles Load Test.

Perform compression load testing in accordance with ASTM D 1143 or tension load testing in accordance with ASTM D 3689 as shown on the plan.

3.5.1 Verification Load Tests.

Install a minimum of 1 non-production verification test pile at each proposed bent for performance testing outside of the proposed footing in conformance with the micropile load test pile details shown on the plans per different soil material. Load the test pile to 200% of the design load. Notify the Engineer 1 week before installing test micropile groups that are to be performance tested. The micropile verification load test results must verify the Contractor's design and installation methods and be reviewed and accepted by the Engineer before beginning installation of production micropiles.

The drilling-and-grouting method, casing length and outside diameter, reinforcing bar lengths, and depth of embedment for the verification test pile(s) must be identical to those specified for the production piles at the given locations. The maximum verification test loads applied to the micropile must not exceed 80% of the structural capacity of the micropile structural elements, to include steel yield in tension, steel yield or buckling in compression, or grout crushing in compression. Any required increase in strength of the verification test pile elements above the strength required for the production piles must be provided for in the contractor's bid price.

3.5.1.1 Testing Equipment and Data Recording

Testing equipment must include dial gauges, dial gauge support, jack and pressure gauge, electronic load cell, and a reaction frame. The load cell is required only for the creep test portion of the verification test.

The contractor must provide a description of test setup and jack, pressure gauge and load cell calibration curves in accordance with the Submittals Section.

Design the testing reaction frame to be sufficiently rigid and of adequate dimensions such that excessive deformation of the testing equipment does not occur. Align the jack, bearing plates, and stressing anchorage such that unloading and repositioning of the equipment will not be required during the test.

Apply and measure the test load with a hydraulic jack and pressure gauge. The pressure gauge must be graduated in 72 psi increments or less. The jack and pressure gauge must have a pressure range not exceeding twice the anticipated maximum test pressure. Jack ram travel must be enough to allow the test to be done without resetting the equipment. Monitor the creep test load hold during verification tests with both the pressure gauge and the electronic load cell. Use the load cell to accurately maintain a constant load hold during the creep test load hold increment of the verification test.

Measure the pile top movement with a dial gauge capable of measuring to 0.001 in. The dial gauge must have a travel enough to allow the test to be done without having to reset the gauge. Visually align the gauge to be parallel with the axis of the micropile and support the gauge independently from the jack, pile or reaction frame. Use a minimum of 2 dial gauges when the test setup requires reaction against the ground or single reaction piles on each side of the test pile.

3.5.1.2 Verification Test Loading Schedule

Test verification piles designated for compression or tension load testing to a maximum test load of 2 times the micropile Design Load (DL) shown on the Plans. The verification pile load tests must be made by incrementally loading the micropile in accordance with the following cyclic load schedule for both compression and tension loading:

Table 1
Verification Test Loading Schedule

Step	Loading	Applied Load (AL)	Hold Time (min.)
1	Apply AL		2.5
		0.15 DL	2.5
2	Cycle 1	0.3 DL	2.5
		0.45 DL	2.5
		AL	1
		0.15 DL	1
		0.3 DL	1
		0.45 DL	2.5
3	Cycle 2	0.6 DL	2.5
		0.75 DL	2.5
		0.9 DL	2.5
		1. DL	2.5
		AL	1
		0.15 DL	1
		1. DL	1
4	Cycle 3	1.15 DL	2.5
		1.3 DL	10 to 60 min
		1.45 DL	2.5
		AL	1
		0.15 DL	1
		1.45 DL	1
		1.6 DL	1
		1.75 DL	2.5
5	Cycle 4	1.9 DL	2.5
		2. DL	10
		1.5 DL	5
		1. DL	5
		0.5 DL	5
		AL	5

Measure pile top movement at each load increment. Start the load hold period as soon as each test load increment is applied. Monitor the verification test pile for creep at the 1 Design Load (DL). Measure and record pile movement during the creep test at 1, 2, 3, 4, 5, 6, 10, 20, 30, 50, and 60 min. The alignment load must not exceed 5% of the DL load. Dial gauges must be reset to zero after the initial AL is applied.

3.5.1.3 **Acceptance.** The acceptance criteria for micropile verification load tests are:

1. The pile must sustain the first compression or tension 1 DL test load with no more than 1 in. total vertical movement at the top of the pile, relative to the position of the top of the pile before testing.
2. At the end of the 1.30 DL creep test load increment, test piles must have a creep rate not exceeding 0.039 in/log cycle time (1 to 10 min.) or 0.079 in/log cycle time (6 to 60 min. or the last log cycle if held longer). The creep rate must be linear or decreasing throughout the creep load hold period.
3. Failure does not occur at the 2 DL maximum test load. Failure is defined as load where the slope of the load versus head settlement curve first exceeds 0.25 in/kip.

The Engineer will provide the Contractor written confirmation of the micropile design and construction within 3 working days of the completion of the verification load tests. This written confirmation will either confirm the capacities and bond lengths specified in the Working Drawings for micropiles or reject the piles based upon the verification test results.

3.5.1.4 **Verification Test Pile Rejection**

If a verification tested micropile fails to meet the acceptance criteria, the Contractor must modify the design, the construction procedure, or both. These modifications may include modifying the installation methods, increasing the bond length, or changing the micropile type. Any modification that necessitates changes to the structure must require the Engineer's prior review and acceptance. Any modifications of design or construction procedures or cost of additional verification test piles and load testing must be at the Contractor's expense. At the completion of verification testing, test piles must be removed down to 2 feet below finished ground or as shown on plans.

3.5.2. **Proof Load Tests.**

Perform proof load tests on production piles as shown in the contract plans and directed by the Engineer. Notify the Engineer 1 week before installing test micropiles that are to be performance tested.

3.5.2.1 **Proof Test Loading Schedule**

Test piles designated for compression or tension proof load testing to a maximum test load of 1.60 times the micropile Design Load shown on the Plans. The maximum proof test loads applied to the micropile must not exceed 80 percent of the structural capacity of the micropile structural elements, to include steel yield in tension, steel yield or buckling in compression, or grout crushing in compression.

Proof tests must be made by incrementally loading the micropile in accordance with the following schedule, to be used for both compression and tension loading:

Table 2
Proof Test Loading Schedule

Step	Loading	Applied Load (AL)	Hold Time (min.)
1	Apply AL		2.5
		0.15 Design Load (DL)	2.5
		0.3 DL	2.5
		0.45 DL	2.5
		0.6 DL	2.5
		0.75 DL	2.5
2	Load Cycle	0.9 DL	2.5
		1. DL	2.5
		1.15 DL	2.5
		1.3 DL	10 to 60 min.
		1.45 DL	2.5
		1.6 DL	2.5
		1.3 DL	4
		1. DL	4
3	Unload Cycle	0.75 DL	4
		0.5 DL	4
		0.25 DL	4
		AL	4

Depending on performance, either a 10 min. or 60 min. creep test must be performed at the 1.30 Design Load (DL) Test Load. Where the pile top movement between 1 and 10 min. exceeds 0.04 in., maintain the Maximum Test Load an additional 50 min. Record movements at 1, 2, 3, 5, 6, 10, 20, 30, 50 and 60 min. The alignment load must not exceed 5 percent of DL. Dial gauges must be reset to zero after the initial AL is applied.

3.5.2.2 Acceptance.

The acceptance criteria for micropile proof load tests are:

1. The pile must sustain the compression or tension 1 DL test load with no more than 1 in. total vertical movement at the top of the pile, relative to the position of the top of the pile before testing.
2. At the end of the 1.3DL creep test load increment, test piles must have a creep rate not exceeding 0.039 in/log cycle time (1 to 10 min.) or 0.079 in/log cycle time (6 to 60 min.). The creep rate must be linear or decreasing throughout the creep load hold period.
3. Failure does not occur at the 1.6DL maximum test load. Failure is defined as load where the slope of the load versus head settlement curve first exceeds 0.25 in/kip.

3.5.2.2 Proof Test Pile Rejection.

If a proof tested micropile fails to meet the acceptance criteria, the Contractor must immediately proof test another micropile within that footing. For failed piles and further construction of other piles, the Contractor must modify the design, the construction procedure, or both. Any modification that necessitates changes to the structure will require the Engineer's approval before review and acceptance. Any modifications of design or construction procedures, or cost of additional for proof load testing, or replacement production micropiles, must be at the Contractor's expense.

4. MEASUREMENT

Micropiles will be measured by the foot of acceptable micropiles in place. The micropiles length measured is the length of the drilled and grouted hole as specified on the plans or modified by the Engineer. Micropiles load tests, both verification load tests and proof load tests, are subsidiary to this Item.

5. PAYMENT

The contract unit price paid for micropile includes full compensation for designing and furnishing all labor, materials, tools, equipment, and incidentals, for doing all the work involved in constructing micropiles, including casings, grout, reinforcement, cutting tips, drill bits, pile anchorage, and disposing of materials resulting from pile installation, complete in place, as shown on the plans, as specified in the Standard Specifications and this special specification, and as directed. Performance test micropiling, including anchor piles, will not be paid for directly but will be subsidiary to the micropiling.

No payment will be made for micropiles that are damaged either during installation or after the micropiles are complete in place. No payment will be made for additional excavation, backfill, concrete, reinforcement, nor other costs incurred from footing enlargement resulting from replacing rejected micropiles.